Automated Fabrication Technologies For High Performance Polymer Composites

Mark J. Shuart, Norman J. Johnston & H. Benson Dexter
NASA Langley Research Center
Hampton, VA

Joseph M. Marchello & Raymond W. Grenoble
Old Dominion University
Norfolk, VA

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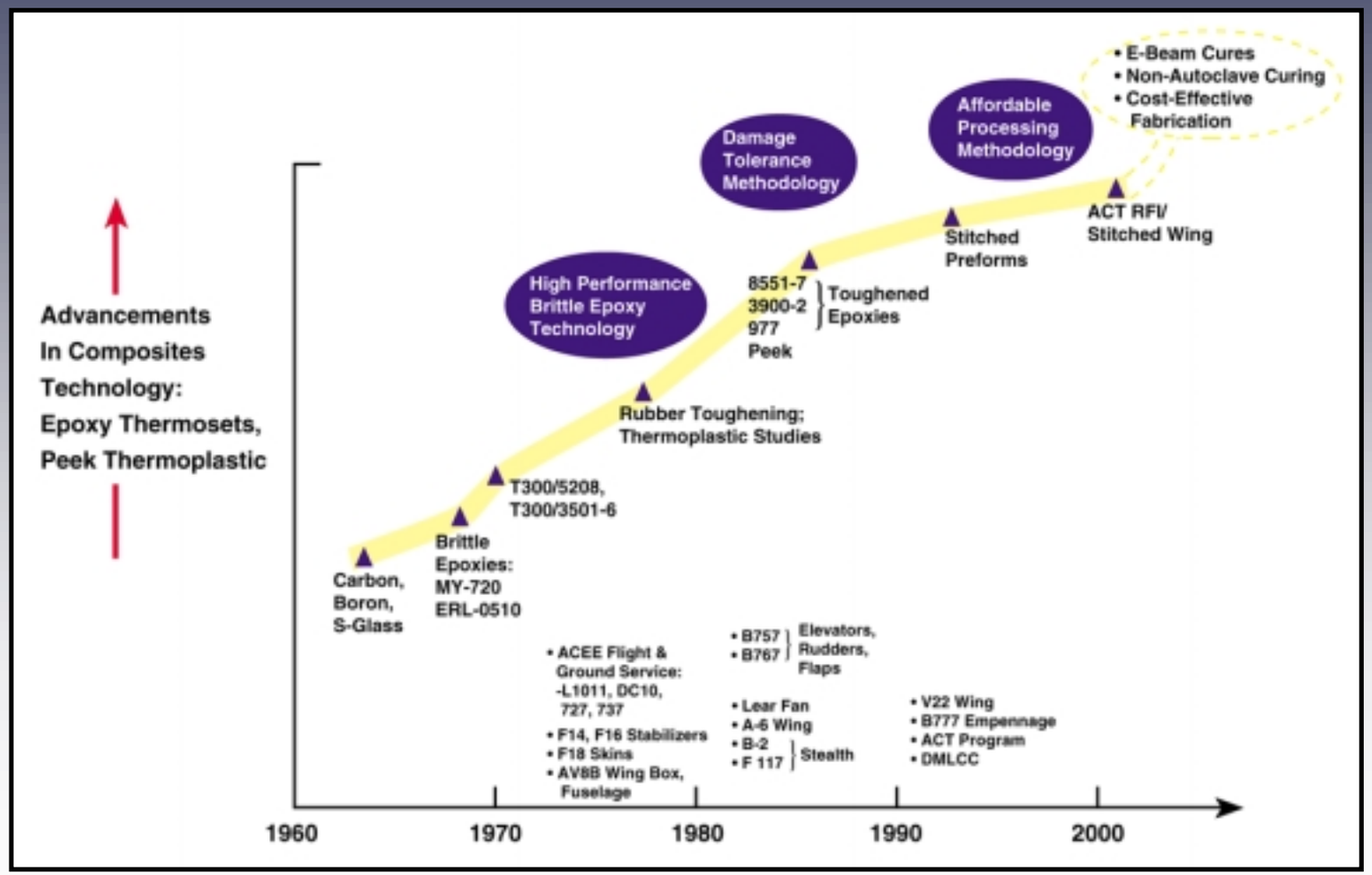
Evolution of Composite Resin Development
Epoxy Thermosets & Peek Thermoplastics



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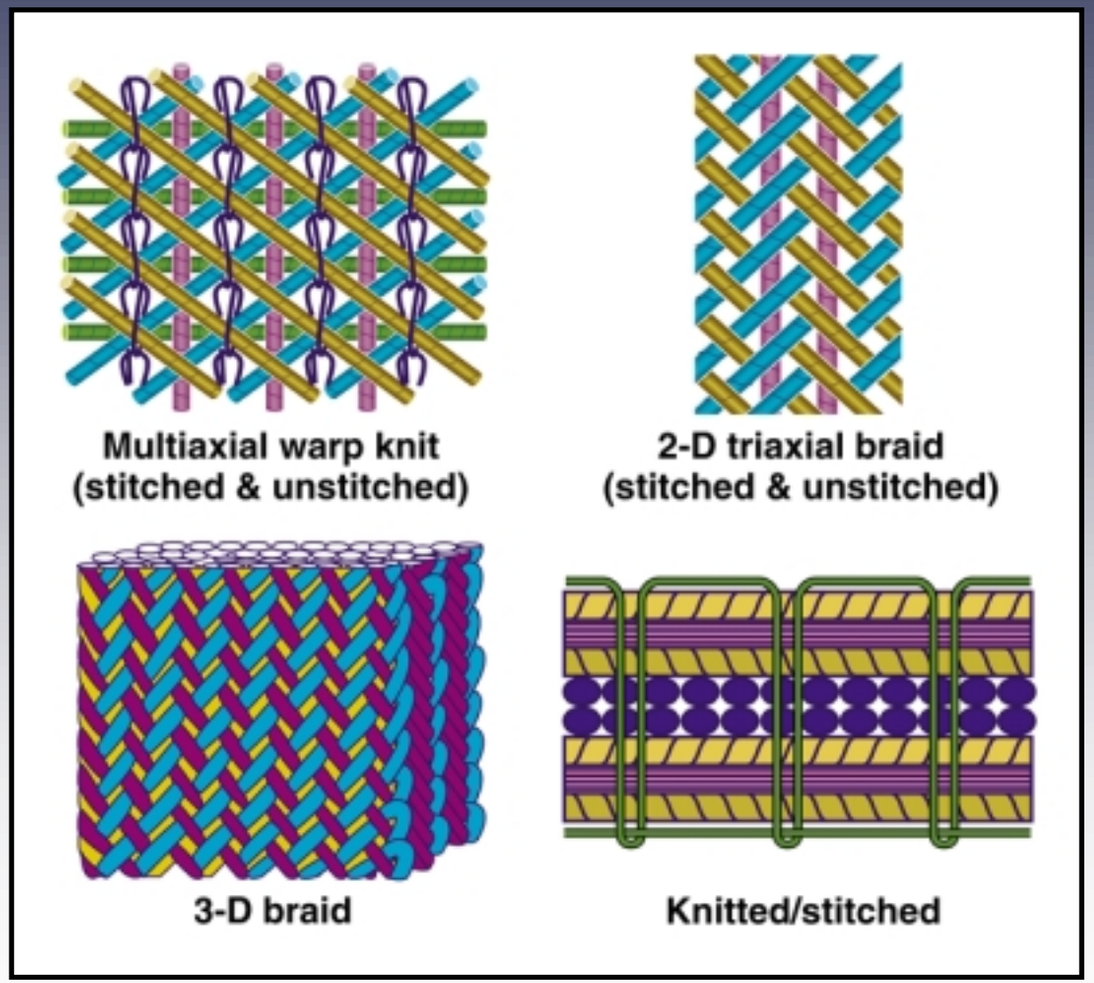
Keys to Low-Cost Composite Fabrication Processes for Airframe Structures

- Low cost fiber forms and matrices
- Automated processes
  - high speed textile processes
  - advanced fiber placement
- Non-autoclave curing
  - vacuum-assisted resin transfer molding
  - cure-on-the-fly
- Low-cost tooling
- In-process control/nondestructive evaluation

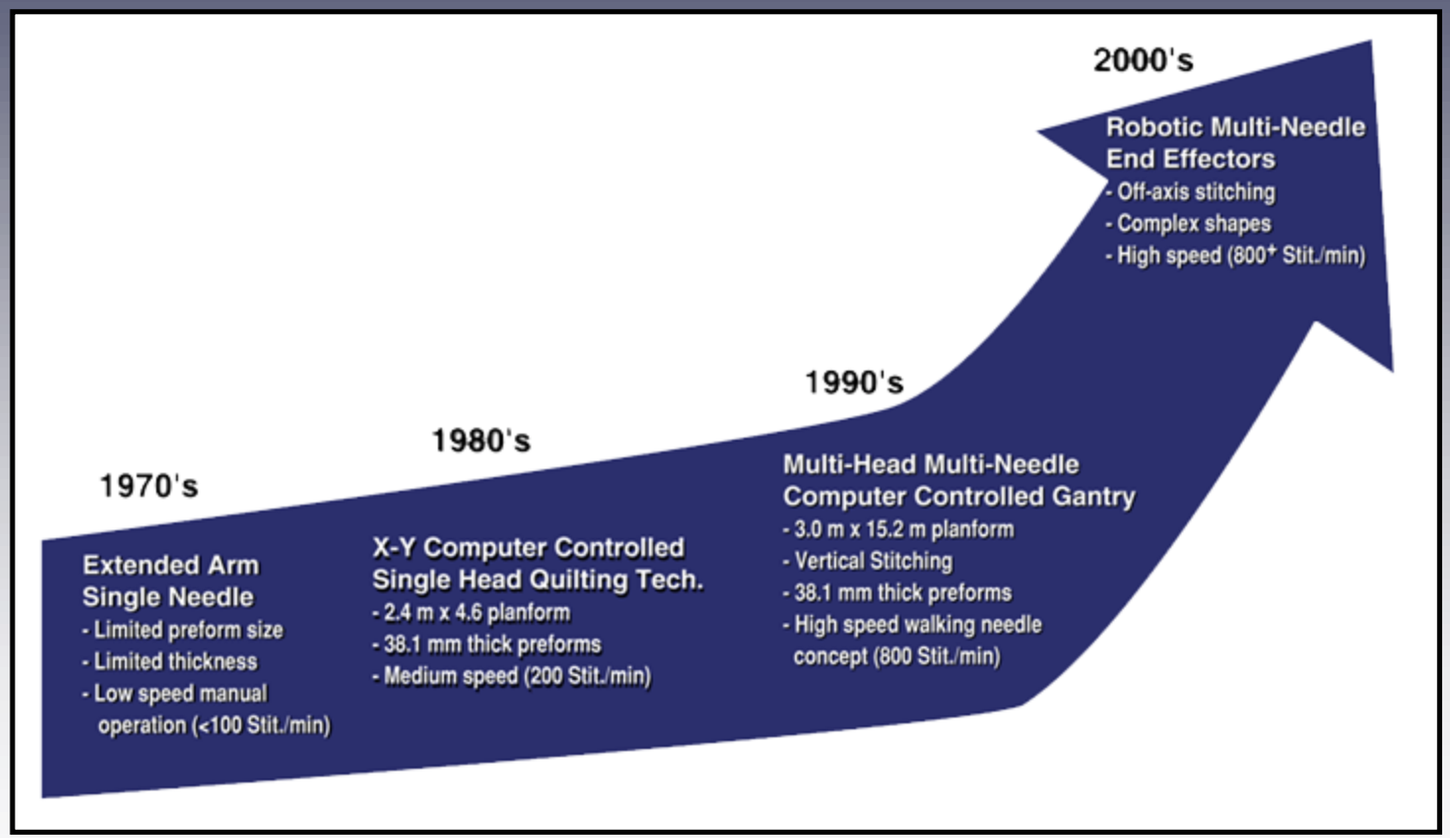
Automated Fabrication Technologies for High Performance Polymer Composites

- Vacuum Assisted Resin Transfer Molding (VARTM)
- Resin Film Infusion (RFI)
- Automated Placement
  - autoclave processing
  - non-autoclave processing

Textile Material Forms



Evolution of Stitching Technology



Stitched Semi-Span Wing Lower Cover Preform

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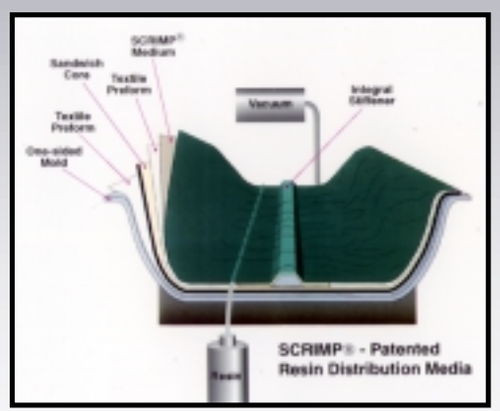
Low-Cost Vacuum Assisted Resin Transfer Molding Process

90 ft, one-piece boat hull fabricated with SCRIMP® process



SCRIMP ® - Patented resin distribution media

Advantages of low-cost RTM process:

- Resin and fiber used in lowest cost form
- Prepreg process eliminated
- Freezer storage & shelf life problems eliminated
- Low-cost, one-sided tooling
- Low energy, low pressure out-of-autoclave processing
- Utilizes net-shape, damage tolerant textile preforms secondary bonding and fastening

Challenges for aircraft applications:

- *Out-of-autoclave cure resins with adequate properties*
- *Dimensional tolerances with low-cost tooling*

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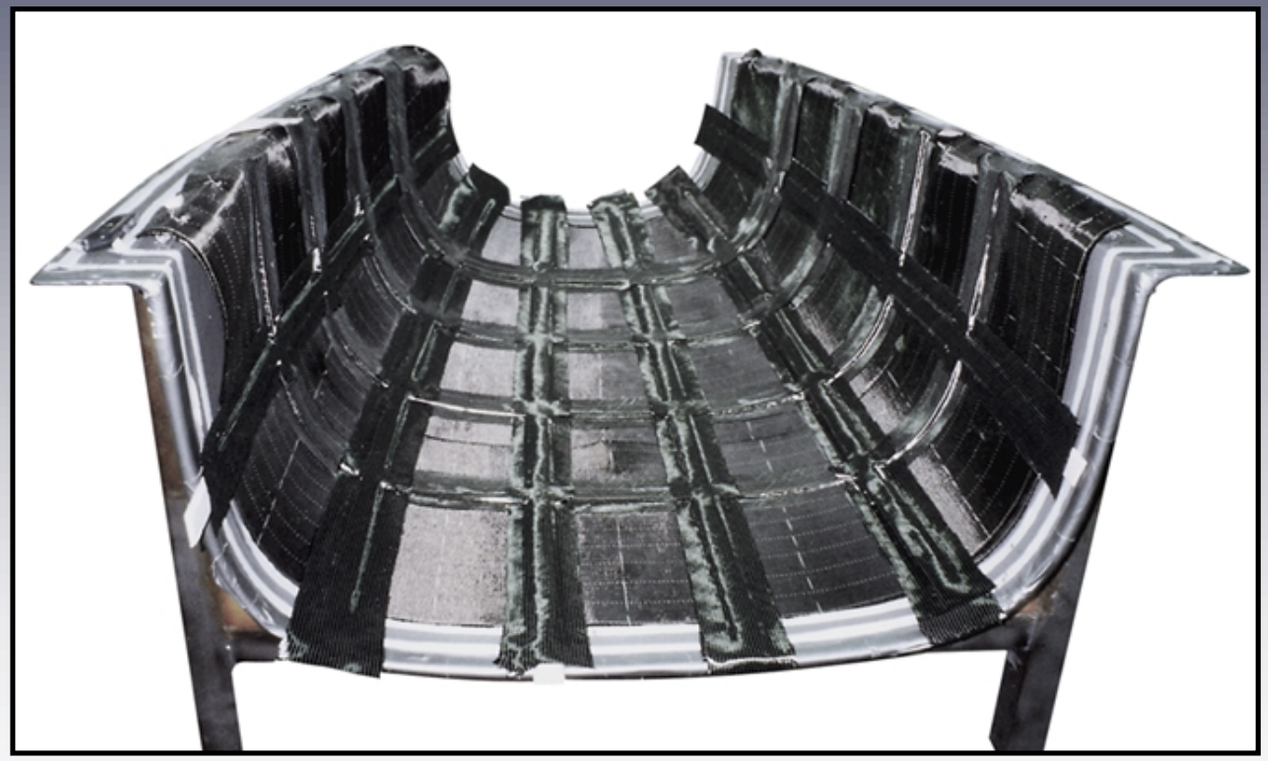
Vacuum Assisted Resin Transfer Molding Tooling For Fuselage Section



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Vacuum Assisted Resin Transfer Molded Fuselage Section

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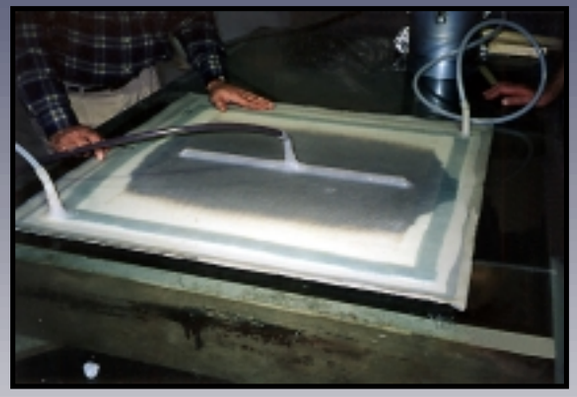
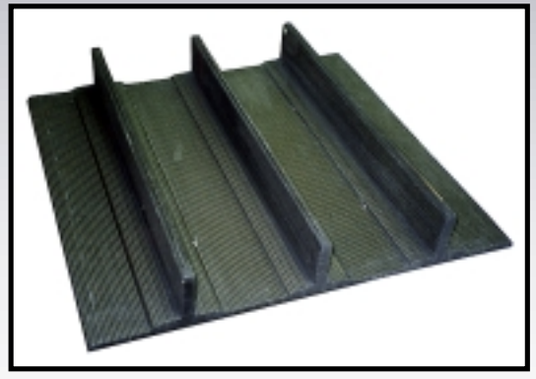
Vacuum Assisted Resin Transfer Molding Process Development



Reusable Vacuum Bag for Flat Panel

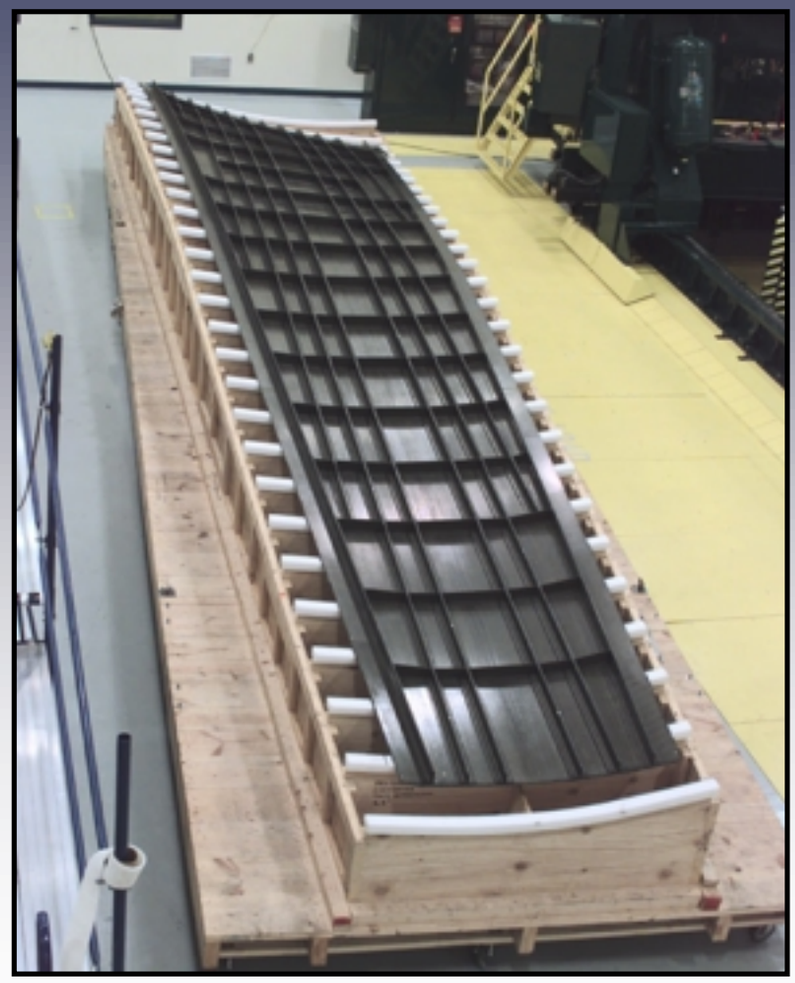
Reusable Vacuum Bag for Stiffened Panel



Stiffened Panel After Cure

Vacuum Bagged Semi-Span Wing Tool Proof Article Prior to Cure

Semi-Span Wing Tool Proof Article After Cure



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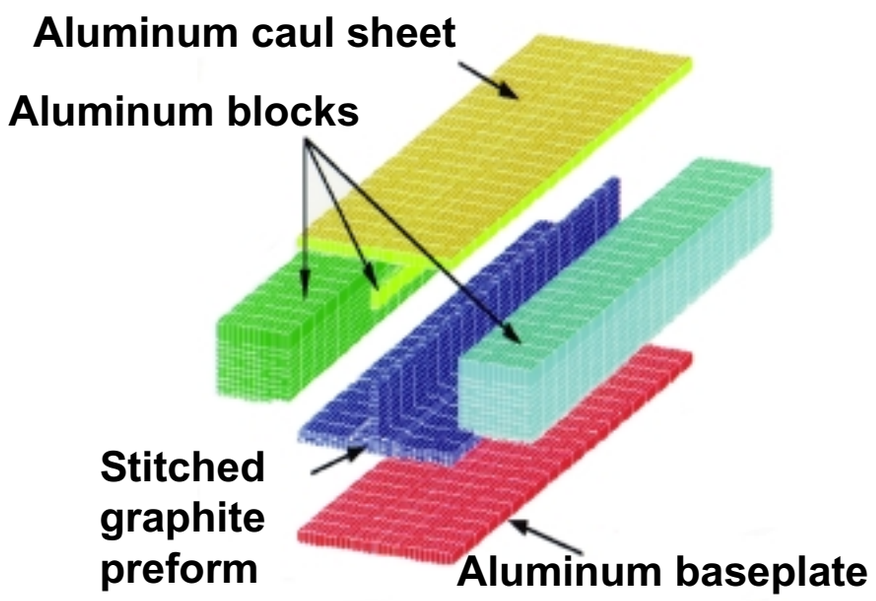
Three-Dimensional Resin Film Infusion Model

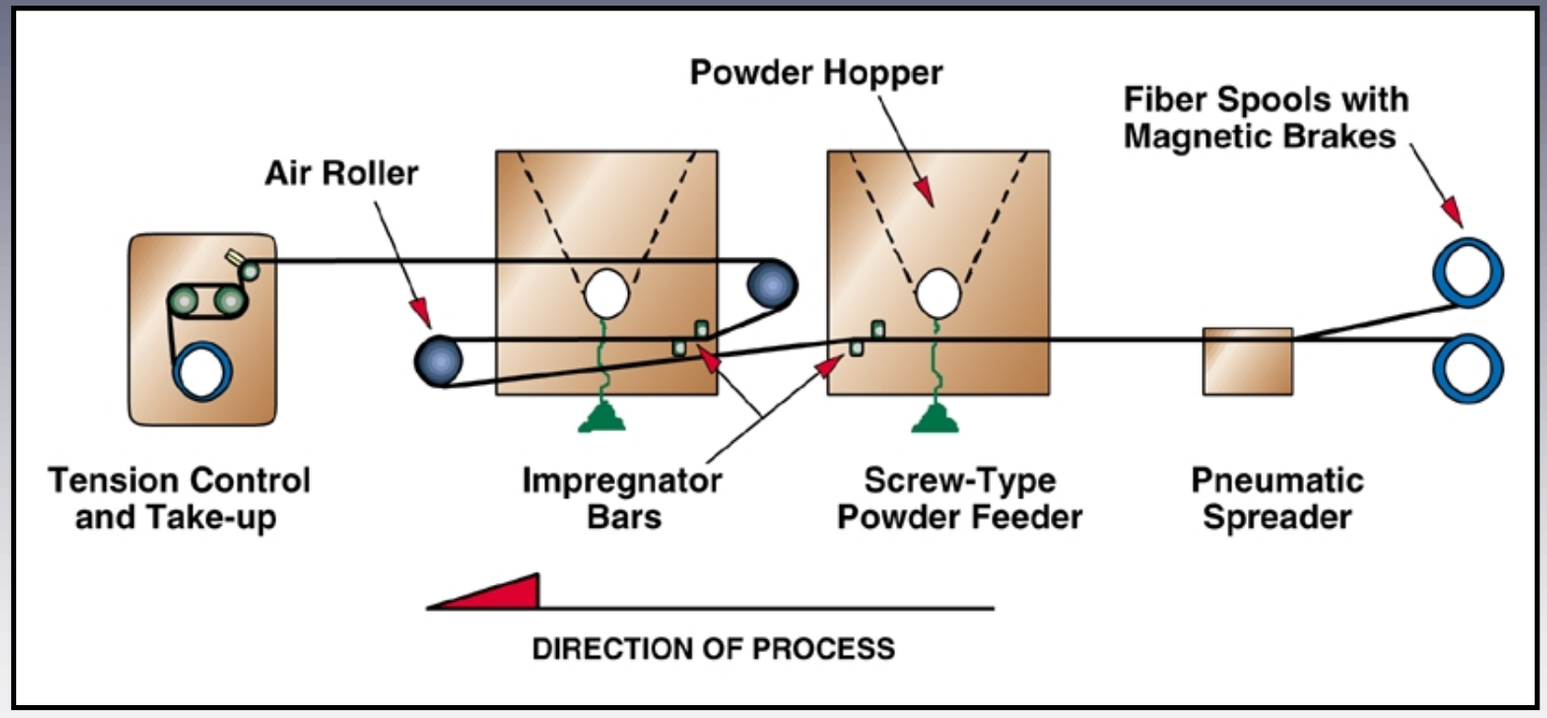
Ply Drop Off Single Blade Stiffener Preform/Tooling Assembly



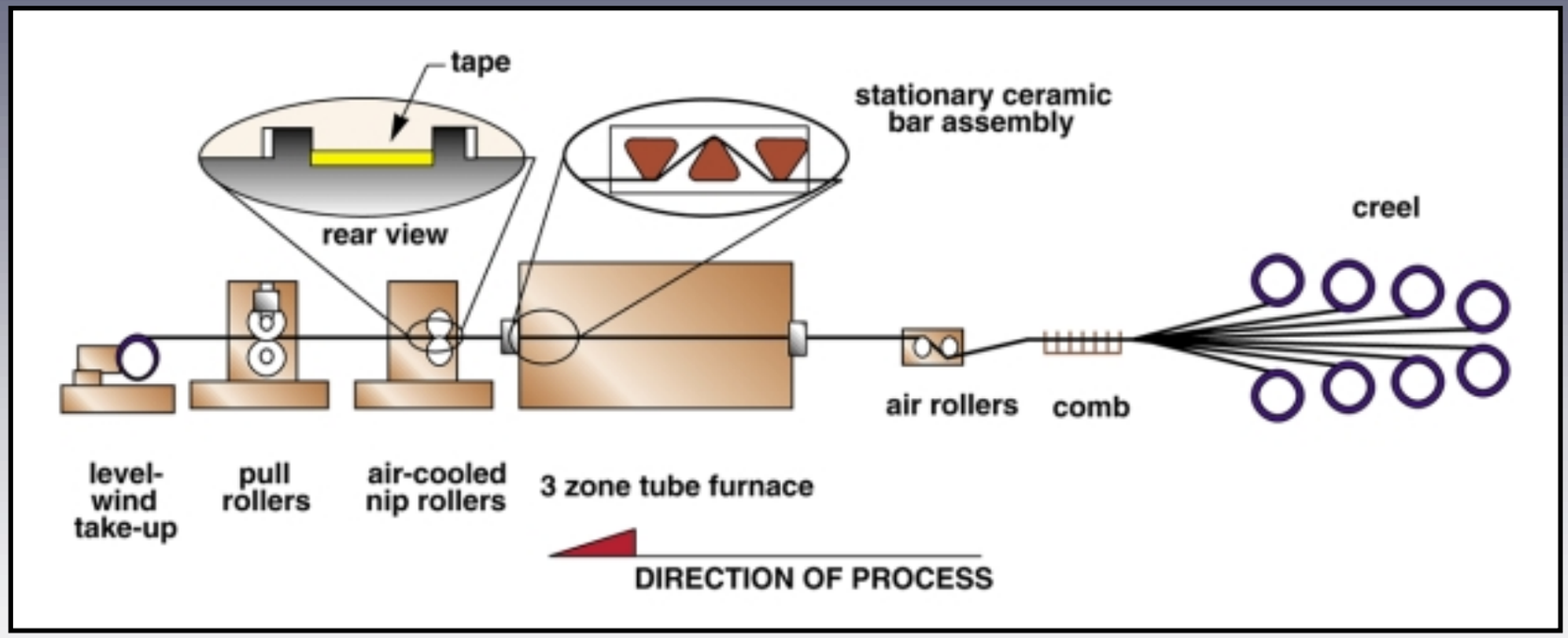
Program Structure

- Flow
- Heat Transfer
- Resin Kinetics
- Resin Viscosity
- Preform Compaction
- Residual Stress and Warpage

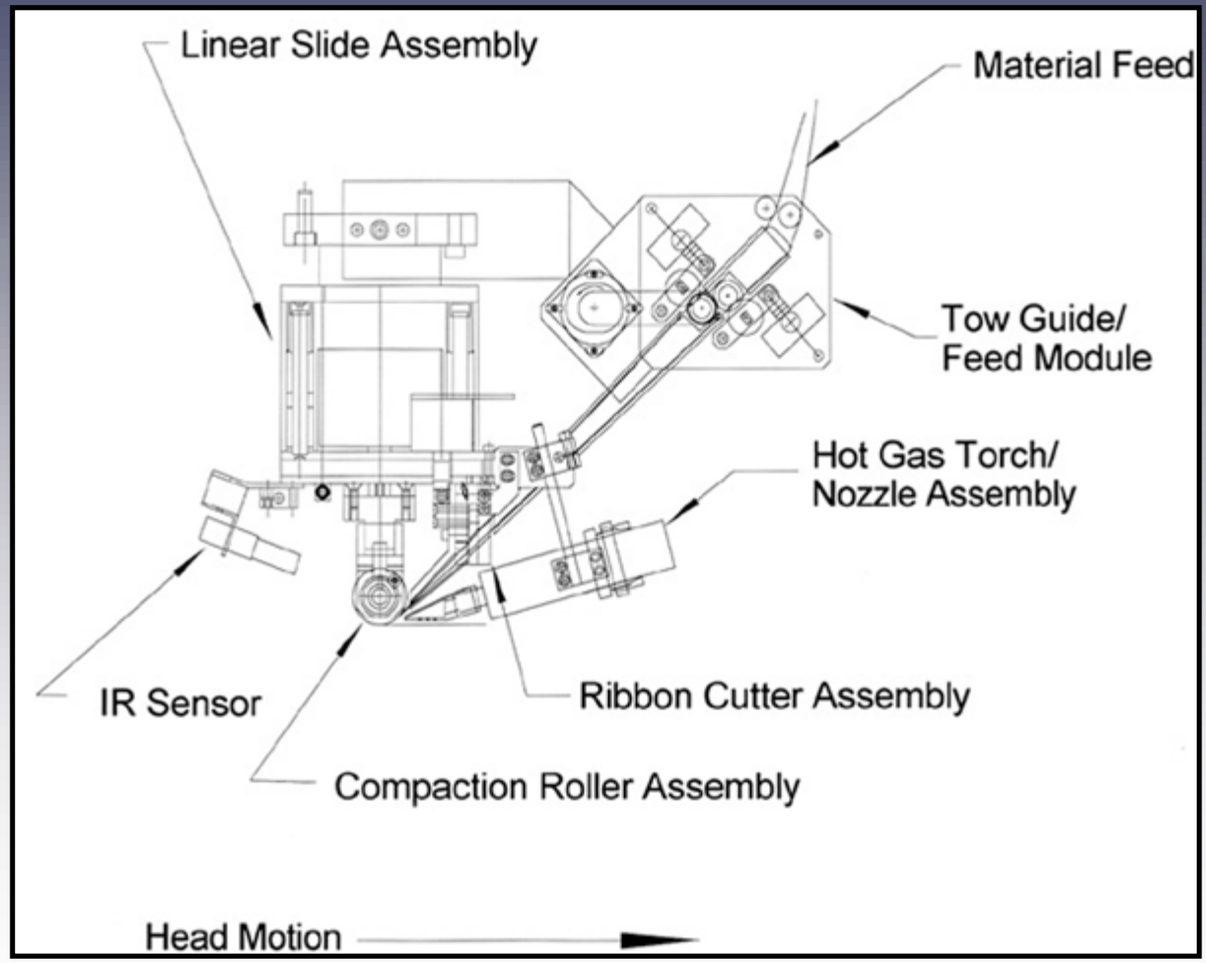
Schematic of The NASA Powder-Coating Line



Schematic of NASA Ribbon/Tape Line

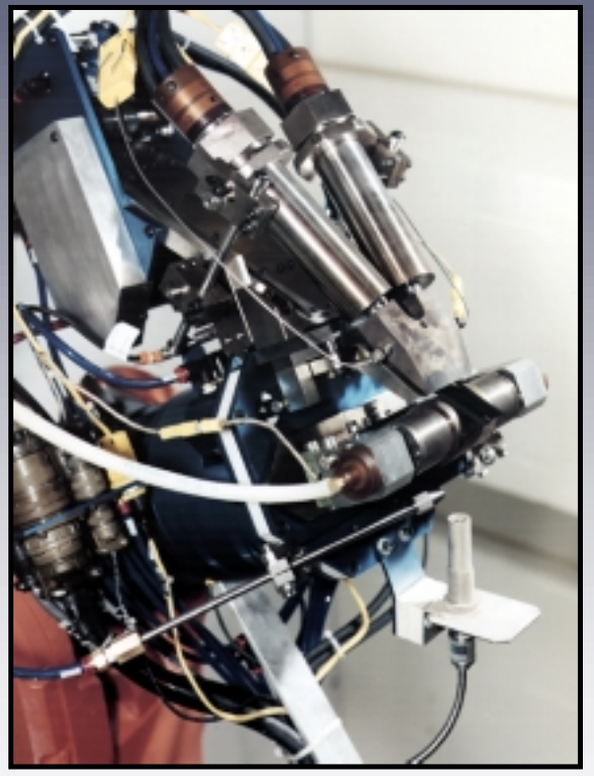


5-Ribbon Thermoplastic Fiber Placement Head



NASA Developed Robot, Heated Head and Heated Flat Tool

NASA Developed Heated Head Laying Ribbon on a Flat Tool



Tool-Side View NASA Developed Heated Head

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Concluding Remarks

- Automated fabrication technologies are required to achieve widespread, cost-effective application of composite structures in transport aircraft
- Major advancements have been made in fabrication of primary aircraft structures with damage-tolerant textile material forms and Resin Film Infusion (RFI) processes
- Vacuum Assisted Resin Transfer Molding (VARTM) of composite structures offers an attractive cost-effective alternative to autoclave cured composites
- Significant progress has been demonstrated for heated-head, cure-on-the-fly automated placement fabrication methods applied to flat and curved composite structures